

1       ~~1. A device for detecting a specific material that~~  
2       may be present in an ensemble of objects comprising means to  
3       expose an area of the ensemble to x-ray energies to produce  
4       dual energy image information of the ensemble and means to  
5       computer-process such dual energy information to detect said  
6       specific material on the basis of comparisons of selected  
7       subareas of said exposed area to other subareas in the  
8       vicinity of said selected subareas.

1       ~~2. A device for detecting a bomb that may be~~  
2       present in a container of objects comprising means to expose  
3       an area of the container to x-ray energies to produce dual  
4       energy image information of the container and its contents  
5       and means to computer-process such dual energy information  
6       to detect said bomb on the basis of comparisons of selected  
7       subareas of said exposed area to other subareas in the  
8       vicinity of said selected subareas.

1       3. A device for detecting a specific material that  
2       may be present in an ensemble of objects comprising means to  
3       expose an area of the ensemble to x-rays of at least two  
4       substantially different energy bands to produce dual energy  
5       image information of the ensemble and means to computer-  
6       process such dual energy information to detect said specific  
7       material on the basis of comparisons between attenuation  
8       image information from at least one of said energy bands and  
9       positionally corresponding image information of parameter P  
10      values derived from correlations of said dual energy image  
11      information with values in a predetermined lookup table  
12      reflecting attenuation at high and low energy bands over a  
13      range of thicknesses of a selected specific material and a  
14      range of thicknesses of a representative overlay material,  
15      with attenuation of a constant thickness of said overlay

16 material and varying thicknesses of said specific material  
17 represented by said parameter P.

1 4. The device of claim 3 wherein the means to  
2 computer-process includes means for evaluating gradients of  
3 values in at least one of the images.

1 5. The device of claim 4 wherein the means to  
2 computer-process includes means for evaluating gradients of  
3 values in both said attenuation image and said image of P  
4 values.

1 6. The device of claim 4 having means for selecting  
2 the regions of said attenuation image information for said  
3 comparisons on the basis of the steepness of gradients of  
4 attenuation values in said attenuation image.

1 7. The device of claim 4, 5 or 6 wherein said means  
2 for selecting employs an edge finding operator.

1 8. The device of claim 6 including means for  
2 generating gradient values  $H_g$  for substantially all subareas  
3 and means for pruning to remove subareas with  $H_g$  values  
4 below a selected threshold, and means for thereafter  
5 performing said comparisons using the remaining  $H_g$  values.

1 9. A device for detecting and indicating the  
2 probable presence of a specific material in an ensemble of  
3 objects, comprising  
4 means for exposing said item to x-rays of at least  
5 two substantially different energy levels,

6 means for generating for each subarea over the  
7 exposed area a set of data values representing logarithms of  
8 x-ray attenuation at said subarea at each of said energy  
9 levels,

10 means for processing said data for said subarea to  
11 compute the values of (H,L) for said subarea, wherein H is  
12 the logarithm of the attenuation of said x-rays at said  
13 subarea at the higher energy level and L is the logarithm of  
14 the attenuation of said x-rays at said subarea at the lower  
15 energy level, and

16 means for applying an edge finding or gradient  
17 evaluating operator such as a Sobel operator to image data  
18 of at least one energy level,

19 means for generating gradient values  $H_s$  for  
20 substantially all subareas,

21 means for pruning to remove subareas with gradient  
22 values  $H_s$  below a selected gradient threshold,

23 means for determining for remaining subareas with  
24 gradient values  $H_s$  above said selected gradient threshold  
25 parameter P values using a lookup table in computer storage  
26 reflecting x-ray attenuation at high and low energy bands  
27 over a range of thicknesses of said selected specific  
28 material and a range of thicknesses of a representative  
29 overlay material, with attenuation of a constant thickness  
30 of said overlay material and varying thicknesses of said  
31 specific material represented by said parameter P,

32 means for applying said gradient evaluating operator  
33 to P image data formed using said parameter P values for  
34 said remaining subareas,

35 means for generating gradient values  $P_s$  for said  
36 remaining subareas,

37 means for calculating a ratio  $H_s/P_s$  for said  
38 remaining subareas,  
39 means for raising said ratio to a power at least as  
40 large as unity to emphasize large values of said ratio, and  
41 means for storing said ratio  $H_s/P_s$  raised to said  
42 power for substantially all of said remaining subareas.

1 10. The device of claim 9 further comprising  
2 means for selecting an alarm threshold on said ratio  
3  $H_s/P_s$  raised to said power so that subareas having said  
4 ratio  $H_s/P_s$  raised to said power above said alarm threshold  
5 are strongly indicative of presence of said specific  
6 material,  
7 means for applying a dilation algorithm using said H  
8 values and said L values for said image data,  
9 means for sounding an alarm if a certain number of  
10 subarea values are above said alarm threshold,  
11 means for applying an erosion algorithm to eliminate  
12 spurious noise in said image data, and  
13 means for displaying said image data with areas of  
14 particular interest highlighted.

1 11. A device for detecting and indicating the  
2 probable presence of a specific material in an ensemble of  
3 objects, comprising  
4 means for exposing said item to x-rays of at least  
5 two substantially different energy levels,  
6 means for generating for each subarea over the  
7 exposed area a set of data values representing logarithms of  
8 x-ray attenuation at said subarea at each of said energy  
9 levels,  
10 means for filtering said data for said subarea,

11 means for averaging said data for said subarea,  
12 means for processing said data for said subarea to  
13 compute the values of (H,L) for said test subarea, wherein H  
14 is the logarithm of the attenuation of said x-rays at said  
15 subarea at the higher energy level and L is the logarithm of  
16 the attenuation of said x-rays at said subarea at the lower  
17 energy level, and  
18 means for applying an edge finding or gradient  
19 evaluating operator such as a Sobel operator to image data  
20 of at least one energy level,  
21 means for generating gradient values  $H_s$  for  
22 substantially all subareas,  
23 means for pruning to remove subareas with gradient  
24 values  $H_s$  below a selected gradient threshold,  
25 means for determining for remaining subareas with  
26 gradient values  $H_s$  above said selected gradient threshold  
27 parameter P values using a lookup table in computer storage  
28 reflecting x-ray attenuation at high and low energy bands  
29 over a range of thicknesses of said selected specific  
30 material and a range of thicknesses of a representative  
31 overlay material, with attenuation of a constant thickness  
32 of said overlay material and varying thicknesses of said  
33 specific material represented by said parameter P,  
34 means for applying said gradient evaluating operator  
35 to P image data formed using said parameter P values for  
36 said remaining subareas,  
37 means for generating gradient values  $P_s$  for said  
38 remaining subareas,  
39 means for calculating a ratio  $H_s/P_s$  for said  
40 remaining subareas,  
41 means for raising said ratio to a power at least as  
42 large as unity to emphasize large values of said ratio,

43 means for storing said ratio  $H_s/P_s$  raised to said  
44 power for substantially all of said remaining subareas,  
45 means for selecting an alarm threshold on said ratio  
46  $H_s/P_s$  raised to said power so that subareas having said  
47 ratio  $H_s/P_s$  raised to said power above said alarm threshold  
48 are strongly indicative of presence of said specific  
49 material,  
50 means for applying a dilation algorithm using said H  
51 values and said L values for said image data,  
52 means for sounding an alarm if a certain number of  
53 subarea values are above said alarm threshold,  
54 means for applying an erosion algorithm to eliminate  
55 spurious noise in said image data, and  
56 means for displaying said image data with areas of  
57 particular interest highlighted.

1 12. A device for inspecting an ensemble of physical  
2 objects comprising means to expose an area of said ensemble  
3 to x-rays of at least two substantially different energy  
4 bands, detection means responsive to said x-rays passing  
5 through said ensemble to generate for subareas over said  
6 area respective sets of values representing the attenuation  
7 of said x-rays at each of said energy bands, comparison  
8 means operative on differences in attenuation between  
9 subareas in a neighborhood to determine the presence of a  
10 specific material in the neighborhood, and indicating means  
11 responsive to said comparisons for indicating presence of  
12 said specific material in said ensemble.

1 13. The device of claim 12 wherein said comparison  
2 means includes a lookup table reflecting attenuation at high  
3 and low energy bands over a range of thicknesses of a

4 selected specific material and a range of thicknesses of a  
5 representative overlay material, with attenuation of a  
6 constant thickness of said overlay material and varying  
7 thicknesses of said specific material represented by a  
8 parameter P.

1 14. The device of claim 13 including means to  
2 reference actual attenuation measurements of subareas at an  
3 energy band with parameter P values for said subareas, and  
4 using said determination in determining the presence of said  
5 specific material.

1 15. The device of claim 12 wherein said comparison  
2 means include means to combine, according to a predetermined  
3 formula, values representing the attenuation of said x-rays  
4 for subareas in said neighborhood to provide an attenuation  
5 measure and means to compare said measure to a reference  
6 related to said specific material.

1 16. The device of claim 12 wherein said values  
2 generated representing the attenuation of said x-rays at  
3 said energy bands are logarithms of x-ray attenuation at  
4 each of said energy bands at each subarea.

1 17. The device of claim 12 wherein said comparison  
2 means comprises means for computing for a selected test  
3 subarea of said area the values ( $H_T, L_T$ ) wherein  $H_T$  is the  
4 logarithm of the attenuation of said x-rays at said higher  
5 energy band at said test subarea and  $L_T$  is the logarithm of  
6 the attenuation of said x-rays at said lower energy band at  
7 said test subarea, means for computing for a subarea nearby  
8 said test subarea the values ( $H_B, L_B$ ) wherein  $H_B$  is the

9 logarithm of the attenuation of said x-rays at said higher  
10 energy band at said nearby subarea and  $L_B$  is the logarithm  
11 of the attenuation of said x-rays at said lower energy band  
12 at said nearby subarea, said comparison means constructed to  
13 employ said values  $(H_T, L_T)$  and  $(H_B, L_B)$  in determining the  
14 presence of said specific material.

1 18. The device of claim 17 further comprising means  
2 for providing p-values P representing attenuation  
3 characteristics of various overlying materials, means for  
4 associating a p-value  $P_T$  with said values  $(H_T, L_T)$  wherein  
5 said p-value  $P_T$  is proportional to the thickness of  
6 overlying materials at said test subarea, means for  
7 associating a p-value  $P_B$  with said values  $(H_B, L_B)$  wherein  
8 said p-value  $P_B$  is proportional to the thickness of  
9 overlying materials at said nearby subarea, means for  
10 computing the value of  $|(H_T - H_B) / (P_T - P_B)| = \Delta H / \Delta P$  and means  
11 for associating  $\Delta H / \Delta P$  with a relative probability measure  
12 for the presence of said specific material at respective  
13 subareas.

1 19. The device of claim 18 wherein the relative  
2 probability measure is proportional to  $(\Delta H / \Delta P)^q$ , wherein q  
3 is a value chosen to emphasize extrema of the value of  
4  $\Delta H / \Delta P$ .

1 20. The device of claim 19 wherein  $q=2$ .

1 21. The device of claim 18 wherein said means for  
2 associating a p-value P with said values  $(H, L)$  involves  
3 identifying said values with respective points from a set of  
4 points previously generated by numerically varying



5 thicknesses of said specific material and said overlying  
6 materials.

1           22. The device of claim 17 wherein said comparison  
2 means comprises means for computing the value of  
3  $(H_T - H_B) / (L_T - L_B) = K_{TB}$  and means for comparing said value of  
4  $K_{TB}$  with the value of  $K_{MAT}$  wherein  $K_{MAT}$  is an attenuation  
5 characteristic of said specific material.

1           23. The device of claim 22 wherein  $K_{MAT}$  is a stored  
2 value developed by prior measurements.

1           24. The device of claim 22 wherein  
2  $K_{MAT} = \mu_H / \mu_L$  wherein  $\mu_H$  is the attenuation coefficient of  
3 said specific material exposed to said higher energy band  
4 x-rays and  $\mu_L$  is the attenuation coefficient of said  
5 specific material exposed to said lower energy band x-rays.

1           25. The device of claim 12 further comprising means  
2 for exposing selected numbers of samples of various known  
3 materials each of a range of different thicknesses to said  
4 x-rays of said different energy bands to measure the  
5 attenuation characteristic of the exposed samples to provide  
6 a reference for said comparison means.

1           26. The device of claim 25 including calculation  
2 means for interpolating between said measured values to  
3 estimate intermediate values for use in making said  
4 comparison.

1           27. The device as in any of claims 3-26 further  
2 comprising means for assigning to subareas over said exposed

3 area of the object relative probabilities for the presence  
4 of said specific material based upon said comparisons, said  
5 indicating means being responsive to said relative  
6 probability assignments for indicating presence of said  
7 specific material in said object.

1 28. A baggage inspection device for detecting and  
2 indicating the probable presence of a specific material in  
3 an item of baggage comprising means to expose an area of  
4 said item to x-rays of at least two substantially different  
5 energy bands, detection means responsive to said x-rays  
6 passing through said item to generate for subareas over said  
7 area respective sets of values representing the attenuation  
8 of said x-rays at each of said energy bands, comparison  
9 means operative on differences in attenuation between  
10 subareas in a neighborhood to determine the presence of a  
11 specific material in the neighborhood of said subareas, and  
12 indicating means responsive to said comparisons for  
13 indicating presence of said specific material in said item,  
14 said comparison means comprising means for computing for a  
15 selected test subarea of said area the values ( $H_T, L_T$ )  
16 wherein  $H_T$  is the logarithm of the attenuation of said  
17 x-rays at said higher energy band at said test subarea and  
18  $L_T$  is the logarithm of the attenuation of said x-rays at  
19 said lower energy band at said test subarea, means for  
20 computing for a subarea nearby said test subarea the values  
21 ( $H_B, L_B$ ) wherein  $H_B$  is the logarithm of the attenuation of  
22 said x-rays at said higher energy band at said nearby  
23 subarea and  $L_B$  is the logarithm of the attenuation of said  
24 x-rays at said lower energy band at said nearby subarea,  
25 said comparison means constructed to employ said values

26  $(H_T, L_T)$  and  $(H_B, L_B)$  in determining the presence of said  
27 specific material.

1           29. The device of claim 28 wherein said comparison  
2 means comprises  
3           means for providing p-values P representing  
4 attenuation characteristics of various overlying materials,  
5           means for associating a p-value  $P_T$  with said values  
6  $(H_T, L_T)$  wherein said p-value  $P_T$  is proportional to the  
7 thickness of overlying materials at said test subarea, means  
8 for associating a p-value  $P_B$  with said values  $(H_B, L_B)$   
9 wherein said p-value  $P_B$  is proportional to the thickness of  
10 overlying materials at said nearby subarea, means for  
11 computing the value of  $|(H_T - H_B)/(P_T - P_B)| = \Delta H/\Delta P$  and means  
12 for associating  $\Delta H/\Delta P$  with a relative probability measure  
13 for the presence of said specific material at respective  
14 subareas.

1           30. The device of claim 13, 14, 18 or 29, including  
2 means for examining said subareas,  
3           means responsive thereto for producing values for  
4 each subarea indicative of the relative probability of  
5 matching said specific material,  
6           means for displaying subareas over said area, and  
7           means for highlighting those subareas having a  
8 probability greater than or equal to a selected threshold  
9 value of matching said specific material.

1           31. The device of claim 28 wherein said comparison  
2 means comprises means for computing the value of  
3  $(H_T - H_B)/(L_T - L_B) = K_{TB}$  and means for comparing said value of

4  $K_{TB}$  with the value of  $K_{MAT}$  wherein  $K_{MAT}$  is an attenuation  
5 characteristic of said specific material.

1 32. The device of claim 17 or 28, wherein  $K_{MAT} =$   
2  $\mu_H(H_T, L_T, H_B, L_B) / \mu_L(H_T, L_T, H_B, L_B)$  wherein  $\mu_H$  is an attenuation  
3 coefficient of said specific material exposed to said higher  
4 energy x-rays, comprising a function of the logarithms of  
5 the attenuation of said x-rays at said test subarea and at  
6 said nearby subarea, wherein  $\mu_L$  is an attenuation  
7 coefficient of said specific material exposed to said lower  
8 energy x-rays, comprising a function of said logarithms of  
9 the attenuation of said x-rays at said test subarea and at  
10 said nearby subarea.

1 33. The device of claim 32 including  
2 means for ascertaining whether said value of  $K_{TB}$  is  
3 within a selected window of values of  $K_{MAT}$ ,  
4 means for incrementing a respective counter if said  
5 value of  $K_{TB}$  is within said window,  
6 means for examining said subarea counters and  
7 producing values for each subarea indicative of the relative  
8 probability of matching said specific material,  
9 means for displaying subareas over said area, and  
10 means for highlighting those subareas having a  
11 probability greater than or equal to a selected threshold  
12 value of matching said specific material.

1 34. The device of claim 1, 2, 3 or 12 wherein said  
2 means to expose said area further comprises an x-ray source,  
3 means for generating from said source x-rays of at least two  
4 substantially different energy bands, means for collimating

5 a fan beam of said x-rays, and means for conveying said  
6 object to intercept said fan beam of said x-rays.

1 35. The device of claim 12, wherein said indicating  
2 means is a visual display of an x-ray image, and said  
3 indication being of the form of distinguished subareas at  
4 which the specific material is probably present.

1 36. The device of claim 1, 2, 3, 12 or 28, wherein  
2 said specific material is a threatening substance.

1 37. The device of claim 36, wherein said threatening  
2 substance is an explosive.

1 38. The device of claim 1, 2, 3, 12 or 28, wherein  
2 said specific material is an illicit drug substance.

1 39. The device of claim 1, 3 or 12, wherein said  
2 ensemble comprises components of a stream of matter.

1 40. The device of claim 39, wherein said stream is  
2 comprised of rocks and other materials, and said specific  
3 material is a mineral of value.

1 41. The device of claim 39, wherein said stream is  
2 shredded plastic refuse, and said specific material is a  
3 particular form of plastic.

1 42. The device of claim 41, wherein said particular  
2 form of plastic comprises halogenated hydrocarbon plastic to  
3 be separated from other plastic refuse.

1           43. The device of claim 1, 3 or 12, wherein said  
2   ensemble comprises foodstuffs.

1           44. The device of claim 43, wherein said foodstuffs  
2   are meat, and wherein said specific material is bone.

1           45. The device of claim 43, wherein said specific  
2   material is inorganic.

1           46. The device of claim 1 or 2 further comprising  
2   means for locating edges in the exposed area where one  
3   material overlaps another, means for choosing subareas in  
4   close proximity to said edges to be said selected subareas,  
5   and means for assigning to said selected subareas a relative  
6   probability for the presence of said specific materials at  
7   said subareas based upon said comparisons with other  
8   subareas in the vicinity, and indicating means responsive to  
9   said relative probability assignment.

1           47. The device of claim 12 further comprising means  
2   for locating edges in the exposed area where one material  
3   overlaps another, means for choosing subareas in close  
4   proximity to said edges to be said selected subareas, and  
5   means for assigning to said selected subareas a relative  
6   probability for the presence of said specific materials at  
7   said subareas based upon comparisons with other subareas in  
8   the neighborhood, said indicating means being responsive to  
9   said relative probability assignment.

1           48. The device of claim 1, 2, 12, 46 or 47 further  
2   comprising means for dilating indications of subareas over  
3   regions whose edges have been determined to indicate the  
4   presence of said specific material, wherein said dilation

5 makes said regions more prominently noticeable to an  
6 operator of said device, and wherein said dilation enhances  
7 indication of presence of said specific material.

1           49. A method of detecting a specific material that  
2 may be present in an ensemble of objects comprising exposing  
3 an area of the ensemble to x-ray energies to produce dual  
4 energy image information of the exposed ensemble and  
5 computer-processing such dual energy information to detect  
6 said specific material on the basis of comparisons of  
7 selected subareas of said exposed area to other subareas in  
8 the vicinity of said selected subareas.

1           50. A method of detecting a bomb that may be  
2 present in a container of objects comprising exposing an  
3 area of the container to x-ray energies to produce dual  
4 energy image information of the exposed container and  
5 computer-processing such dual energy information to detect  
6 said bomb on the basis of comparisons of selected subareas  
7 of said exposed area to other subareas in the vicinity of  
8 said selected subareas.

1           51. A method of baggage inspection for detecting and  
2 indicating the probable presence of a specific material in  
3 an item of baggage, comprising the steps of  
4           exposing said item to x-rays of at least two  
5 substantially different energy levels,  
6           generating for each subarea over the exposed area a  
7 set of data values representing logarithms of x-ray  
8 attenuation at said subarea at each of said energy levels,  
9           choosing a test subarea,  
10          filtering said data for said test subarea,  
11          averaging said data for said test subarea,

12           processing said data for said test subarea to  
13   compute the values of  $(H_T, L_T)$  for said test subarea, wherein  
14    $H_T$  is the logarithm of the attenuation of said x-rays at  
15   said test subarea at the higher energy level and  $L_T$  is the  
16   logarithm of the attenuation of said x-rays at said test  
17   subarea at the lower energy level, and  
18           choosing a background subarea,  
19           filtering said data for said background subarea,  
20           averaging said data for said background subarea,  
21           processing said data for said background subarea to  
22   compute the values of  $(H_B, L_B)$  for said background subarea,  
23   wherein  $H_B$  is the logarithm of the attenuation of said  
24   x-rays at said background subarea at the higher energy level  
25   and  $L_B$  is the logarithm of the attenuation of said x-rays at  
26   said background subarea at the lower energy level, and  
27           computing the value of  $K_{TB} = (H_T - H_B) / (L_T - L_B)$ , and  
28           comparing said value of  $K_{TB}$  to the value of  $K_{MAT}$ ,  
29   wherein  $K_{MAT} = \mu_H(H_T, L_T, H_B, L_B) / \mu_L(H_T, L_T, H_B, L_B)$  wherein  $\mu_H$ , an  
30   attenuation coefficient of a specific material exposed to  
31   said higher energy x-rays, is a function of the logarithms  
32   of the attenuation of said x-rays at said test subarea and  
33   at said background subarea, wherein  $\mu_L$ , an attenuation  
34   coefficient of said specific material exposed to said lower  
35   energy x-rays, is a function of the logarithms of the  
36   attenuation of said x-rays at said test subarea and at said  
37   background subarea, and  
38           ascertaining whether said value of  $K_{TB}$  is within a  
39   selected window of values of  $K_{MAT}$ , incrementing a respective  
40   counter if said value of  $K_{TB}$  is within said window,  
41           choosing another background subarea, and  
42           iterating the steps from filtering said data for  
43   said background subarea to choosing another background



44 subarea until a substantial number of background subareas  
45 have been so examined, and  
46 choosing another test subarea, and  
47 iterating the steps from filtering said data for  
48 said test subarea to choosing another test subarea until  
49 substantially all subareas have been so tested, and  
50 examining said subarea counters,  
51 producing values for each subarea indicative of the  
52 relative probability of matching said specific material, and  
53 displaying subareas over said area, and  
54 highlighting those subareas having a probability  
55 greater than or equal to a selected threshold value of  
56 matching said specific material.

1 52. A method of baggage inspection for detecting  
2 and indicating the probable presence of a specific material  
3 in an item of baggage, comprising the steps of  
4 exposing said item to x-rays of at least two  
5 substantially different energy levels,  
6 generating for each subarea over the exposed area a  
7 set of data values representing logarithms of x-ray  
8 attenuation at said subarea at each of said energy levels,  
9 choosing a test subarea,  
10 filtering said data for said test subarea,  
11 averaging said data for said test subarea,  
12 processing said data for said test subarea to  
13 compute the values of  $(H_T, L_T)$  for said test subarea, wherein  
14  $H_T$  is the logarithm of the attenuation of said x-rays at  
15 said test subarea at the higher energy level and  $L_T$  is the  
16 logarithm of the attenuation of said x-rays at said test  
17 subarea at the lower energy level, and  
18 choosing a background subarea,

19 filtering said data for said background subarea,  
 20 averaging said data for said background subarea,  
 21 processing said data for said background subarea to  
 22 compute the values of  $(H_B, L_B)$  for said background subarea,  
 23 wherein  $H_B$  is the logarithm of the attenuation of said x-  
 24 rays at said background subarea at the higher energy level  
 25 and  $L_B$  is the logarithm of the attenuation of said x-rays at  
 26 said background subarea at the lower energy level, and  
 27 providing p-values  $P$  representing attenuation  
 28 characteristics of various overlying materials,  
 29 associating a p-value  $P_T$  with said values  $(H_T, L_T)$   
 30 wherein said p-value  $P_T$  is proportional to the thickness of  
 31 overlying materials at said test subarea,  
 32 associating a p-value  $P_B$  with said values  $(H_B, L_B)$   
 33 wherein said p-value  $P_B$  is proportional to the thickness of  
 34 overlying materials at said nearby subarea,  
 35 computing the value of  $|(H_T - H_B) / (P_T - P_B)| = \Delta H / \Delta P$ ,  
 36 associating  $\Delta H / \Delta P$  with a relative probability  
 37 measure for the presence of said specific material at  
 38 respective subareas,  
 39 storing said probability measure,  
 40 choosing another background subarea, and  
 41 iterating the steps from filtering said data for  
 42 said background subarea to choosing another background  
 43 subarea until a substantial number of background subareas  
 44 have been so examined, and  
 45 choosing another test subarea, and  
 46 iterating the steps from filtering said data for  
 47 said test subarea to choosing another test subarea until  
 48 substantially all subareas have been so tested, and  
 49 examining said subarea probability measure stores,

50           producing values for each subarea indicative of the  
51 relative probability of matching said specific material, and  
52           displaying subareas over said area, and  
53           highlighting those subareas having a probability  
54 greater than or equal to a selected threshold value of  
55 matching said specific material.

1           53. A method of detecting a specific material that  
2 may be present in an ensemble of objects comprising the  
3 steps of

4           exposing an area of the ensemble to x-rays of at  
5 least two substantially different energy bands to produce  
6 dual energy image information of the ensemble, and  
7           computer-processing such dual energy information to  
8 detect said specific material on the basis of comparisons  
9 between attenuation image information from at least one of  
10 said energy bands and positionally corresponding image  
11 information of parameter P values derived from correlations  
12 of said dual energy image information with values in a  
13 predetermined lookup table reflecting attenuation at high  
14 and low energy bands over a range of thicknesses of a  
15 selected specific material and a range of thicknesses of a  
16 representative overlay material, with attenuation of a  
17 constant thickness of said overlay material and varying  
18 thicknesses of said specific material represented by said  
19 parameter P.

1           54. A method of detecting and indicating the  
2 probable presence of a specific material in an ensemble of  
3 objects, comprising the steps of

4           exposing said item to x-rays of at least two  
5 substantially different energy levels,

6           generating for each subarea over the exposed area a  
7   set of data values representing logarithms of x-ray  
8   attenuation at said subarea at each of said energy levels,  
9           filtering said data for said subarea,  
10          averaging said data for said subarea,  
11          processing said data for said subarea to compute the  
12   values of (H,L) for said test subarea, wherein H is the  
13   logarithm of the attenuation of said x-rays at said subarea  
14   at the higher energy level and L is the logarithm of the  
15   attenuation of said x-rays at said subarea at the lower  
16   energy level, and  
17          applying an edge finding or gradient evaluating  
18   operator such as a Sobel operator to image data of at least  
19   one energy level,  
20          generating gradient values  $H_s$  for substantially all  
21   subareas,  
22          pruning to remove subareas with gradient values  $H_s$   
23   below a selected gradient threshold,  
24          determining for remaining subareas with gradient  
25   values  $H_s$  above said selected gradient threshold parameter P  
26   values using a lookup table in computer storage reflecting  
27   x-ray attenuation at high and low energy bands over a range  
28   of thicknesses of said selected specific material and a  
29   range of thicknesses of a representative overlay material,  
30   with attenuation of a constant thickness of said overlay  
31   material and varying thicknesses of said specific material  
32   represented by said parameter P,  
33          applying said gradient evaluating operator to P  
34   image data formed using said parameter P values for said  
35   remaining subareas,  
36          generating gradient values  $P_s$  for said remaining  
37   subareas,

38 calculating a ratio  $H_s/P_s$  for said remaining  
39 subareas,  
40 raising said ratio to a power at least as large as  
41 unity to emphasize large values of said ratio,  
42 storing said ratio  $H_s/P_s$  raised to said power for  
43 substantially all of said remaining subareas,  
44 selecting an alarm threshold on said ratio  $H_s/P_s$   
45 raised to said power so that subareas having said ratio  
46  $H_s/P_s$  raised to said power above said alarm threshold are  
47 strongly indicative of presence of said specific material,  
48 applying a dilation algorithm using said H values  
49 and said L values for said image data,  
50 sounding an alarm if a certain number of subarea  
51 values are above said alarm threshold,  
52 applying an erosion algorithm to eliminate spurious  
53 noise in said image data, and  
54 displaying said image data with areas of particular  
55 interest highlighted.

1 55. The method as in any of claims 49-54 further  
2 comprising employing computed tomographic information to  
3 detect said specific material that may be present in  
4 subareas indicated by said computer-processed dual energy  
5 information as being probable subareas for the presence of  
6 said specific materials.

1 56. For use in detecting a specific material that  
2 may be present in an area being exposed to x-ray energies, a  
3 lookup table in computer storage reflecting x-ray  
4 attenuation at high and low energy bands over a range of  
5 thicknesses of said selected specific material and a range  
6 of thicknesses of a representative overlay material, with

97

- 91 -

- 7 attenuation of a constant thickness of said overlay material  
8 and varying thicknesses of said specific material  
9 ~~represented by a parameter P.~~

add  
B1

add  
C4

add  
D1

add  
E3